

NEW PHYSICS SEARCHES WITH PHOTONS IN CDF*

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A brief review of searches for physics beyond the Standard Model with photons using the CDF detector at the Tevatron is given here. These include searches for supersymmetry, extra dimensions, excited electrons and $W/Z+\gamma$ production, as well as anomalous photon production. Recent results from CDF Run II experiment are presented, but some results from Run I are also reviewed.

1. Introduction

There are a large number of important and well-motivated theoretical models which make a strong case for looking for new physics in events with a photon in the final state. These theories include Supersymmetry (SUSY), Extra Dimensions (ED), Grand Unified Theories, Composite models, Anomalous couplings and Higgs models. On the experimental side CDF detected the $ee\gamma\cancel{E}_T$ candidate event for which there is an *a posteriori* background of rate of 10^{-6} events expected from the Standard Model (SM) processes¹.

Besides the specific theoretical models, searching for new physics with photons has several advantages. For example, the photon is one of the three $SU(2) \times U(1)$ gauge bosons and as such is likely to be a good probe of new interactions since it couples to any new gauge sector. Final-state photons have additional distinct detection advantages over W^\pm or Z^0 bosons since they do not decay. Thus they do not suffer a sensitivity loss from branching ratios and momentum sharing between the decay products. There are very few SM backgrounds which produce photons, allowing a fairly clean signature.

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In this article we summarize the current CDF experimental results of searches for new physics in final states containing energetic photons at the Tevatron.

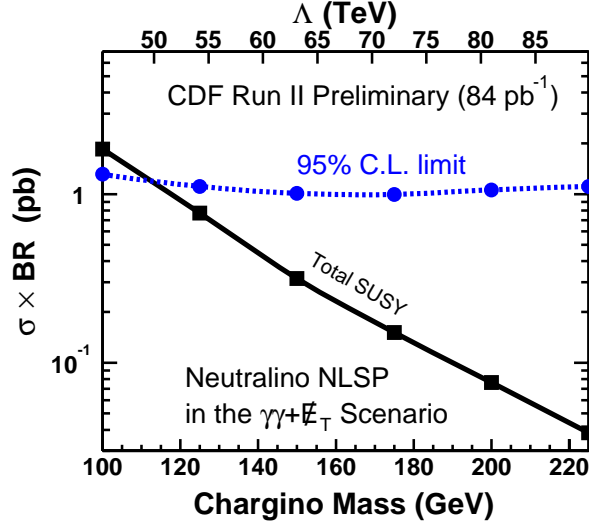


Figure 1. The 95 % C.L. cross section limits from $\gamma\gamma + \cancel{E}_T$ analysis, without background subtraction. Also shown is the total SUSY cross section for the neutralino NLSP as a function of $M_{\tilde{\chi}_1^\pm}$ and Λ .

2. Search for Supersymmetry in $\gamma\gamma + \cancel{E}_T$ Events

Among various SUSY models, two SUSY breaking mechanisms are interesting, which predict photons in the final state. Supergravity models can produce events which decay down to the second lightest neutralino via a loop into the lightest neutralino ($\tilde{\chi}_1^0$) and a photon, where the $\tilde{\chi}_1^0$ is the lightest supersymmetric particle (LSP). Gauge-Mediated SUSY Breaking models (GMSB) with the $\tilde{\chi}_1^0$ decaying into a photon and gravitino can produce a final state of two photons and large missing transverse energy (\cancel{E}_T). \cancel{E}_T is often used as a pointer to possible SUSY signals because it indicates the escape of a non-interacting SUSY particle from the detector. The LSP signals are of particular interest as they provide a natural explanation for the dark matter.

CDF has searched for $\gamma\gamma + \cancel{E}_T$ final state within GMSB scenario using 84 pb⁻¹ of Run II data. Events are selected as having two photon candidates with $E_T > 13$ GeV in the central. We expect a total of $0.77^{+0.40}_{-0.21}$ events with

$\cancel{E}_T > 25$ GeV and two events pass all requirements in the data. The lower mass limit on the lightest chargino derived from this analysis is $M_{\tilde{\chi}_1^\pm} > 113$ GeV at the 95% C.L. lower limit (see Figure 1). Updated analysis is now underway using 200 pb^{-1} data and new results are starting to appear.

3. Searches for Anomalous $\gamma\gamma$ production

CDF has searched for new physics in the Run II diphoton sample. Two isolated photons, each with $E_T > 25$ GeV, are required in the analysis. The main background comes from jets which fake photons. No evidence for new physics was found in this sample. CDF has also performed a search in the diphoton sample for events with an additional lepton (e or μ) and estimate the backgrounds to each of these measurements. All data are well described by the SM expectations.

4. Searches for Anomalous $l\gamma$ production

CDF has performed a model independent search for anomalous production of events with a high E_T photon and a lepton (e or μ) in the final state using Run I data². Several final states were defined, based on the presence of leptons, photons, and \cancel{E}_T . All data sets are consistent with the SM expectations with a possible exception of $l\gamma + \cancel{E}_T$ where 7.6 ± 0.7 events are expected while 16 events are observed. The CDF experiment continues for search the anomalous $l\gamma$ production using Run II data for hints of new physics.

5. Searches for Extra Dimensions

Recent theories postulate the existence of new space-time dimensions. Such extra dimensions might be found by studying the emission of the electromagnetic radiation in Graviton (G) into the EDs, together with single photon or diphoton emitted into the normal dimensions.

CDF has searched for direct G production in the γG final state using Run II data. The analysis required a photon with $E_T > 47$ GeV, $\cancel{E}_T > 42$ GeV, and no jets with $E_T > 10$ GeV in the event. The main backgrounds are from cosmic rays and $Z \rightarrow \nu\bar{\nu}\gamma$. Total 19.8 ± 2.3 events are expected from the backgrounds, and 18 events are observed. No deviation from the SM expectation is observed, and the limit is derived as a ratio to the expected background from the irreducible SM process $q\bar{q} \rightarrow Z\gamma \rightarrow \nu\bar{\nu}\gamma$. The limit is

2 times the expected $Z\gamma$ signal. This is a significant improvement over the Run I, which obtained a limit 3.1 times the $Z\gamma$ signal.

Another way to search for the ED is to look for G exchange processes in the diphoton final state and looking for an excess in the invariant mass distribution. In Run I CDF found no evidence of a signal, and the 95% C.L. lower limit on the effective Plank scale in the ED, M_S , were set at 989 (853) GeV for the Hewett convention, $\Lambda_{\text{Hewett}} = -1 (+1)$. A search for a Randall-Sundrum graviton in the diphoton decay mode is now underway using Run II data and preliminary results are starting to appear.

6. Searches for excited electrons with $e\gamma + e$ Events

CDF uses 72 pb^{-1} of Run II data to search for the production of excited electrons (e^*) using the reaction $p\bar{p} \rightarrow e^* + e \rightarrow e\gamma + e$. This is a signature-based search for a central $ee\gamma$ final state with a resonance in the $e\gamma$ channel. This analysis required two high p_T electrons with an additional photon in the final state. CDF observed no candidate events in the data after making all selections, and set 95 % C.L. limit on the production cross section times $\text{BR}(e^* \rightarrow e\gamma)$, and on the e^* mass for various choices of the compositeness scale λ in the e^* model. For $M_{e^*}=\lambda$, the mass limit is 785 GeV.

7. Searches for $W/Z+\gamma$ production

The associated production of a vector boson and a photon is an ideal test of the triple gauge couplings which are precisely predicted by the SM. Any deviation from the SM could indicate new physics. Several measurement are preformed by the CDF using 73 pb^{-1} of Run II data. All available lepton triggers are used to select W and Z candidates inclusively and the additional photon is then selected.

The cross section for $W\gamma/Z\gamma$ production are measured for $\Delta R_{l\gamma} > 0.7$ and $E_T^\gamma > 7$ GeV and the kinematic distributions are compared to the SM prediction. The $W\gamma$ cross section is measured to be $18.2 \pm 2.9(\text{stat}) \pm 2.3(\text{sys}) \pm 1.1(\text{lumi})$ pb compared to the SM expectation of $18.7 \pm 1.3(\text{theory})$ pb. The $Z\gamma$ cross section is found to be $5.8 \pm 1.3(\text{stat}) \pm 0.7(\text{sys}) \pm 0.3(\text{lumi})$ pb compared to the theoretical prediction of $5.3 \pm 0.4(\text{theory})$ pb. The results are in excellent agreement with the SM expectations.

8. Conclusion

Since the photon is a clean and well measured electromagnetic object, new physics searches with photons are particularly interesting. The CDF ex-

periment is taking data actively since 2001 and larger samples are being collected for new physics searches based on the photon signature. High luminosity data with photons will provide a good opportunity for new physics discoveries, and will give experimental guidance to a better theoretical modeling of new physics production with photons in the final states.

References

1. CDF Collaboration, Phys. Rev. Lett. **81**, 1791 (1998).
2. CDF Collaboration, Phys. Rev. Lett. **89**, 041802 (2002).